About *Micrographia*

Robert Hooke *Micrographia*

London 1665

You are about to open a book that revolutionized the art of scientific investigation. Robert Hooke was still in his twenties when he wrote *Micrographia,* yet in this single volume revealed the immense potential of a single instrument, the microscope, and the many brilliant speculations of a multi-faceted mind. *Micrographia* introduces us to the living cell; to microscopic fungi and the life story of the mosquito; we encounter the two contrasting theories about the origin of the lunar craters posed for the very first time. We read the first sensible proposal for the origin of fossils, and an uncanny prediction of the artificial fiber industry in Hooke's discussion of the spinning of silk by the spider. Elsewhere in his great book, gigantic insects populate the pages, and controversy and scientific argument mark out the text.

Micrographia is a large book, measuring almost twelve inches tall and weighing three pounds. It was printed in October 1664, and when bound copies appeared for sale the following year, it became an instant bestseller. Samuel Pepys – who owned a microscope during his time at the Navy Office – wrote that he liked *Micrographia* better than any other book he had bought, and sat up half the night reading its revelations. The first edition was dated 1665, and was printed with a two-color title page (the key words picked out in red ink). The second followed

in 1667, this time with the title page printed only in black. The book remained popular, and seventy years after it first appeared the plates (minus a few which had been lost or damaged) were reprinted under the editorship of an amateur enthusiast and writer named Henry Baker; this new book was entitled *Micrographia Restaurata* with editions in 1745 and 1780. Plates from Hooke's original studies continued to reappear in the nineteenth century and facsimiles of the original *Micrographia* were published in the twentieth century. There are even current versions in paperback, meaning that the book will remain in print into the third millennium.

Most people cannot relish the crisp printing and the fine paper of an original issue from 1665, and this edition on CD-ROM brings the look of the first edition truly into the public domain. We can marvel at the clarity of the prose, and the vividness of the pictures. Many of the plates (of the stinging nettle, for example, and the louse) reveal minute details not seen again until the era of the scanning electron microscope. It is hard to believe that these are the images from a pioneer who flourished three and a half centuries ago.

Nobody knows what Robert Hooke looked like. Almost uniquely, for a major figure of his time, we have no portrait of the man. There are records that suggest a portrait was painted, and perhaps he was drawn too, but nothing is known to have survived to the present day. I would know him at once if I saw him, however. His manner seems to have been distinctive, for he had a small, hunched body and pale, darting eyes. His gait was urgent and he always walked quickly, giving an impression of boundless nervous energy. He remained constantly active and on the move to near the very end of his life.

Robert Hooke was born on July 18, 1635 in Freshford on the Isle of Wight, a small island just off the south coast of England. A sickly child, he was too ill to attend school regularly, so he was educated at home whenever his father found spare time to teach him. The young Hooke had a penchant for making scientific toys – clocks, model boats, sundials. He had learned enough Greek and Latin by the age of thirteen to gain entrance to Westminster School, London, where he went after his father died. His inheritance of £100 was a very modest sum with which to launch a career.

Robert Hooke excelled at school in London, designing "thirty different ways of flying," and is said to have mastered six books of Euclid in a single week. From Westminster he went up to Oxford University where he worked as an assistant to Thomas Willis and met the great Robert Boyle. Hooke was soon acting as Boyle's research assistant at Boyle's private laboratory in High Street, where he succeeded in perfecting a vacuum pump – these designs of Hooke's were later adapted by the developers of the first steam engines, from which the Industrial Revolution arose.

In 1660 the Royal Society itself was formed, initially as a discussion group, then dignified by royal patronage in 1662 by King Charles II. Destined to become Britain's academy of science, the Royal Society had its roots in the "invisible college," an informal meeting point for young philosophers in London and Oxford. Among the founding members of the new Society was

Robert Boyle. The Fellows were so impressed by his young assistant that they appointed him Curator of Experiments in November 1662; this marked the beginning of Hooke's marvelously creative career.

Microscopes were beginning to attract interest in the scientific community. The design preferred by Hooke was made of a tube of cardboard covered with finely tooled leather. Two glass lenses (an objective, and an eyepiece or field-lens) revealed small details of familiar objects which to Hooke were clearly a key to a greater understanding of the scientific world. Within four months of taking up his job, Hooke was given the specific responsibility of performing microscopical demonstrations for the members of the Royal Society. This appointment came on March 25, 1663, and it launched him on a career that was to take science in a new direction.

His first demonstration came two weeks later on April 8, 1663, and it is in many ways still the least appreciated of them all. Hooke examined the tiny leaflets of a wall moss growing outside on the Royal Society premises, and drew a meticulous study showing the plant in all its magnified intricacy. The plant is drawn larger than life, and the spore-containing capsule is also well portrayed. However, the upper center of the plate (Scheme XIII) contains a crucial detail: the cellular structure of the leaflets is delicately drawn, each separate cell captured by the engraver's line. This was Hooke's first demonstration, and it included a vision of living cells.

The term "cell" was coined by Hooke – but not to describe the living cells visible in his moss specimen. To him, the cell signified a little square room, using it to connote the microscopic structure of a section of cork. His study shows clearly that solid cork is made up of tiny boxes, explaining the properties Hooke observed in cork: that it was highly compressible, that it resisted becoming saturated with water, and that it was exceedingly light. In this way, Robert Hooke used the microscope to explain the physical properties of a familiar substance. His description is clear: "…these pores, or cells, were not very deep, but consisted of a great many little boxes…" To Hooke, the cell was a dead box and not a living entity. However, it is this coinage which we use to this day to denote the unit of life, and it is fascinating to realize that the first drawing Hooke ever made (of moss) had already disclosed the cellular structure of the living plant. The observation on cork was presented to the Royal Society the following week, by which time the Fellows had already become acquainted with the cell. None of them, it seems, realized the importance of the discovery.

A veritable cavalcade of discovery followed. After the demonstration of moss (April 8, 1663) and cork (April 13), came leeches in vinegar and mold on leather (April 22), diamonds in a flint and a spider with six eyes (April 29), then female and male gnats (May 6). He set up the point of a needle, the head of an ant and a fly (May 20), pores in petrified wood and a male gnat (May 27), sage leaves (June 10), and petrified wood again on June 17. Next week, on June 24, Hooke was instructed to join forces with Dr. Wilkins and Dr. Wren to accelerate the program of microscopical demonstrations. These men were important members of Hooke's circle of acquaintances: John Wilkins was the Bishop of Chester who served as Secretary of the Royal Society, while Christopher Wren was a physician, a pioneer of

hypodermic injection – but better known to us for his ventures into architecture, Saint Paul's cathedral, London, being certainly his most famous building.

Early in the next month, on July 6, 1663, Hooke was in Whitehall demonstrating some of these exciting findings to King Charles II. By order of the King, his discoveries were to be collected together in the form of a commemorative book. After this encouragement, Hooke's demonstrations continued apace: the edge of a razor, fine taffeta, and a millipede (July 8); fine lawn; gilt-edged paper and a feather-winged moth (July 16); sea weed, teeth of a snail, a fungus on rose leaves (August 5); and insects in rain water (August 17). The pace of work never slackened. The following summer the Royal Society Minutes tell us that Robert Hooke was requested to bring in two or three good experiments at the next meeting (June 1, 1664), and Mr. Hooke was desired to think upon one or two experiments more (June 29). If ever he was unable to attend a meeting, there were no experiments. And all the while, the idea of compiling his findings into a great book for public sale was forming in his mind.

Robert Hooke was single-minded and businesslike when he set out to write *Micrographia*. He inquired about the likely interest in the subject, and asked his scientist friends (including Christopher Wren) whether they knew of any one else likely to write a competing book. Once he was satisfied he could command the greatest market share, he set about making the book's contents much broader than the title suggests. He used the fashionable microscope theme as a means of attracting public attention, while incorporating a range of his current theories and findings to establish a precedent in print.

The first plate, or scheme, shows Hooke's design for the mercury barometer. Scheme IV shows the behavior of liquids in glass tubes, capillary action, and Prince Ruperts Drops (glass beads that burst violently when pinched). He then describes at length the nature of light, and the existence of spurious colors in feathers and minerals. This theory of light and colors was to lead to bitter conflict with Isaac Newton seven years later, when Hooke rather too airily dismissed his rival theory and claimed that it was all in *Micrographia* anyway. Neither Newton nor Hooke were easy men; this was only the first in a series of disputes over plagiarism and priority that set Hooke's brilliance of insight against Newton's sustained power of analysis.

By Scheme VII Hooke is showing how the shape of crystals can be related to the packing of spherical molecules within them, an observation which helped set the new discipline of crystallography on a scientific footing. Interestingly enough, the only one of Hooke's original drawings to have survived is of ice crystals, the engraved version featured in Scheme VIII. At the head of this plate is an array of snowflakes, and they – unlike the other images in the book – have an appearance which is not like that of snowflakes in nature, looking like caricatures of the real thing. And the reason is simple: Robert Hooke was himself plagiarizing the work of an earlier investigator. His drawings are clearly taken from those published in 1661 by Thomas Bartholin in his *De Nivis usu Medico Observationes Variae*. For all his protestations about contemporaries misappropriating his work, Hooke, it seems, used another's images in his book.

He moves on to portray the origin of fossils in an explanation close to our modern understanding. Hooke describes his exper-

iments with the beard of wild oat (which twists and turns with changes of humidity) and in Scheme XV shows a design for a hygrometer which could harness the effect for scientific purposes. He returns to the refraction of light later in the book, devoting Scheme XXXVII to the subject, before concluding with studies of the lunar craters and stars which he made with a telescope and publishes on Scheme XXXVIII. He shows experimentally that the craters could be made either by upwelling from beneath, or bombardment from above; the controversy between the two continued until recent years.

Robert Hooke was creative in many other fields. He was a noted architect, and one of his surviving buildings may well be the Pepys Library at Cambridge University. He also designed the monument to the great fire of London – often attributed Christopher Wren – but records show it was Hooke who designed this striking column. His work as a surveyor proved him to be a gifted architect. After the astronomical observations recorded in *Micrographia*, Hooke went on to draw surface features on Mars (these were used over a century later when observers timed that planet's period of rotation). He also was the first to propose that Jupiter revolves on its axis. He applied the inverse square law to the orbits of the planets, set out to show that the earth had an elliptical orbit, proposed the wave theory of light, and showed that the length of a spring is a function of the force applied to it. This last is still known as Hooke's Law, and it is through this simple idea that schoolchildren still encounter the name of this great man in classrooms today.

Brian J. Ford

Brian J. Ford

Brian J. Ford is Chairman of the Committee for the History of Biology at the Institute of Biology in London and a Fellow of Cardiff University. He has written reference books and popular works on the development of the microscope, and is well known as a lecturer and broadcaster on radio and television. Among his recent titles are *Images of Science*, *A History of Scientific Illustration and Single Lens*, and *The Story of the Simple Microscope*. He lives and works in Cambridgeshire, England.

Micrographia Binding

The binding of *Micrographia* is contemporary full dark brown calfskin over pasteboard measuring 11 9/16 by 7 3/4 inches (293 x 195 mm). The spine has been re-backed with leather of similar color, weight, approximating the original style and material. The front and back boards have blind rules on the four edges, with two blind double rules running from head to tail, about one-third the distance from the spine; blind arabesque decorations in the ruled corners. The spine, divided into six panels, has original spine pieces reattached on top of re-backing leather. Gilt title on red leather in one panel, the panel below with the emblem of the Earl of Middlesex; other panels tooled with a gilt saltire and flower design.

A modern solander box houses the book. The box is constructed of quarter black morocco with black cloth. The spine is divided into six panels with gilt tooling of the title and band areas.

Provenance This copy of *Micrographia* was formerly in the Badminton Library – Badminton Park in Gloucestershire is the seat of the dukes of Beaufort. It bears on the front pastedown the engraved armorial bookplate of Henry Somerset, second Duke of Beaufort (1684-1714), dated 1705 (Franks, No. 27572). It was three years before that he married Mary Sackville, only daughter of Charles Sackville, Earl of Dorset (1638-1706) who, two years before succeeding to his father's title, had been allowed by King Charles II to style himself Earl of Middlesex. This title had belonged to his uncle, the third and last Earl, whose estates Sackville inherited; the price for the earldom (it is said) was the surrender of his mistress Nell Gwynn to the monarch – Sackville also received "expenses out of pocket." It therefore seems likely that the M on the spine of the binding, with its earl's coronet, indicates a Middlesex heirloom, transferred to Badminton after the marriage.

Click Here to See Binding

Gatherings, Catchwords, Signatures, & Collation

Old books were printed on hand presses not one page at a time on single leaves, but several pages at once on sheets of paper several times larger than the actual page size (Fig. 1). Each sheet was then folded (once or several times) to make a group of leaves, known as a *gathering* (Fig. 2). A series of these gatherings was then stitched together to form a book.

The printer had to ensure that the 4 or 8 or 16 etc. pages that were to be printed together on each large sheet of paper were so arranged that they would appear (after folding) in the proper order (Fig. 1). One means to this end was the use of a *catchword,* a single word printed at the end of an extra line at the foot of the page that matches the first word on the next page, and thus provides a link between the two texts (Fig. 3). Page numbers would of course be just as useful, but not all early books were paginated, and even when they were, the type for pagination (folios) tended to be added to the head or foot of a

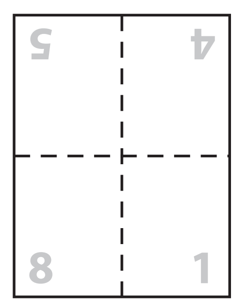

Fig. 1

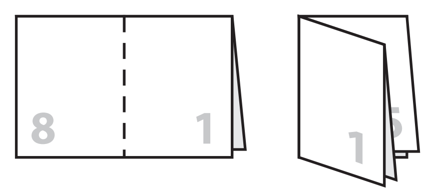

Fig. 2

page just before printing, after the text had already been imposed in its proper order with the aid of the catchwords.

The use of catchwords was adopted from medieval manuscripts and used as early as the 1470s. They were customary in European printing from the mid-sixteenth century to the late eighteenth with some regional variations. In Paris, for instance, printers usually put catchwords only on the final page of each signature. This and many another local practice often enables scholars to assign a date to an undated book or demonstrate that a publisher's claim is false. The title page of an impious or seditious French pamphlet, for instance, may indicate that it was printed and published in London, beyond the jurisdiction of the crown, when it may in fact be evident from compositorial peculiarities that it could only have been printed in Paris, under the nose of the authority it mocked. Fortunately for revolutionaries, bibliographers were not consulted by governments on such matters until the very late nineteenth century.

Catchwords ensure that a group of pages may be printed in the proper order on each large sheet of paper. *Signatures* ensure that a group of sheets may be arranged in the proper order to form a book. Like catchwords, signatures were taken over by the early printers from medieval manuscript practice. Ordinarily they consisted of the letters of the Roman alphabet placed at the bottom of the first page on each sheet, and usually on a few subsequent leaves after the first to assist the binder in folding the sheet into a gathering of leaves (Fig. 4). To avoid confusion between I and J, or U and V (two letters rather than four to the Romans), one of these pairs (almost always the J,

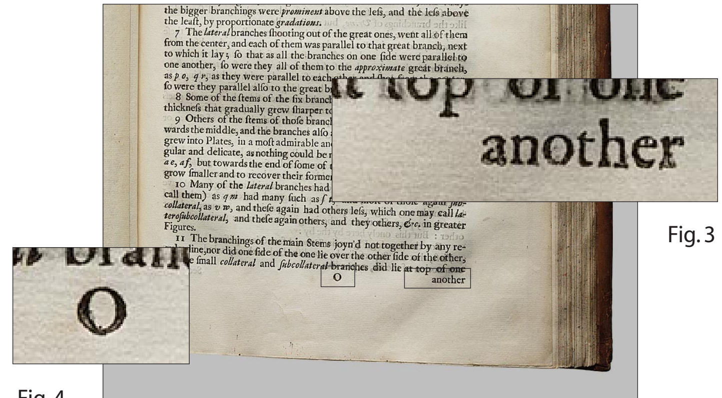

Fig. 3

Fig. 4

and often the U) was usually omitted from the alphabet, as was W (originally regarded, apparently, as merely a "double U"), leaving a 23-letter Latin alphabet. Some printers used as few as 20 letters, omitting X, Y, and Z as well; and some extended the alphabet to 24 by including W. Among these last was a Methodist printer in Bristol, a friend of John Wesley, who may have been attracted to the initial letter. William Colenso's pioneer missionary printing in New Zealand in the 1830s used the Maori alphabet and letter order to sign the sheets: the vowels followed by H, K, M, N, P, R, T, W, and G. Arabic numerals were also occasionally used in fifteenth-century printing, but quickly fell out of use. The practice was revived in the nineteenth century, especially in America, and is now current, at least when signatures are used at all.

Numbers have the advantage of extending on into infinity. Letters as signatures must be repeated with distinguishing

variations if the book is of some length. After 23 signatures (of the conventional printer's alphabet) signed A-Z, the 24th might be signed Aa or 2A; alternatively the first 23 might be signed in lower case a-z, with the 24th through 46th signed in the usual small caps A-Z. Such is the lettering on the first page of every sheet, but several subsequent right-hand pages (rectos) were usually signed as well to help the binder, leading to such formulations as Aa, Aa2, Aa3, and Aa4 at the foot of the first four leaves of an 8-leaf gathering. The next four leaves had no need of a signature; as they were conjugate with (that is, joined along a fold to) the first four, it was physically impossible to misplace them.

Many further variations of signatures are known to be possible, and others await discovery. Their detection offers the scholar, or even the casual reader, one of the few excuses for extended idle browsing in old books. Particularly noticeable are variations in the signatures of preliminary pages. Authors tend to write their prefaces last of all, often when the book is already on press. The printer must therefore allow for an undetermined (but usually small) number of pages that will precede the first signature of text. Some of these signs will have to be inferred: it would spoil an elegant title page to have catchword and signature dangling at the bottom. But elsewhere in the preliminary leaves it is sometimes possible to find an interesting assortment of unusual types, the asterisk, obelus, Maltese cross, paragraph, and various other marks of punctuation. It was more common, however, either to begin setting the type by signing the first page of the main text with the letter B, reserving for A the eventual preliminaries, or to begin the text with a capital A, reserving lower case for the preliminaries – or some combination of the two.

Hooke's *Micrographia,* for instance, is folio in format. That is to say that the large sheets of paper on which it is printed were folded once to form two leaves, or four pages. The book begins with a sheet forming a folio gathering of two unsigned leaves, with the title page on the third page (i.e. the recto of the second leaf). This is followed by another pair of preliminary leaves (signature A) addressing the King and the Royal Society. A further seven folio sheets (signed, in lower case, a through g) contain the actual preface. The main text then begins. Its first two signatures (B and C) are printed in folio as before, but the rest of the text is printed as a quarto. These leaves are signed D through Z and then Aa through Kk. The last two signatures (Ll and Mm), containing most of *The Table* and the errata, revert to folio format.

The way a book is put together, or assembled from the sheets, is called *collation.* Bibliographers, librarians, and booksellers have various shorthand formulas – one might call them bibliographical recipes – for indicating collation. Unsigned preliminary leaves for which no signature letter can be inferred are conventionally assigned the Greek letter pi, thus avoiding the confusion with the Roman letters that do actually appear in the book. The superscript indicates the number of leaves that are produced by the folding of the sheets. To avoid printing great strings of letters – a long book may run through half a dozen alphabets of signatures – bibliographers usually abbreviate Aa to 2A, Aaa to 3A, and so on. This practice has been followed in this collation of Hooke's *Micrographia:*

Collation 2^0: π^2, A^2, a-g^2, B-C^2, D - $2K^4$, 2L-M^2; 146 leaves; pp. [*36*], 1-246, [*10*].

Contents: 1^a: blank. $\pi 1^b$: imprimatur dated Novem. 23. 1664. $\pi 2^a$: title. $\pi 2^b$: blank. $A1^a$ - $A2^b$: dedication TO THE | KING. $A2^b$: dedication TO THE | ROYAL SOCIETY. $a1^a$ -$g2^b$: preface. $B1^a$-$2K3^b$: text. $2K4^a$-$2M2^a$: THE TABLE. $2M2^b$: ERRATA.

Plates I – XXXVIII: Scheme I opp. $g2^b$; Scheme [II] opp. $B1^a$; Scheme III opp. $C1^b$ (p. 6); Scheme IIII opp. $D2^b$ (p. 11); Scheme V opp. $H2^b$ (p.44); Scheme VI opp. $K3^b$ (p. 62); Scheme VII opp. $N1^b$ (p. 82); Scheme VIII opp. $N4^b$ (p. 88); Scheme IX opp. $O3^a$ (p. 93); Scheme X opp. $Q2^a$ (p. 107); Scheme XI opp. $R2^a$ (p. 115); Scheme XII opp. $S3^a$ (p. 125); Scheme [XIII] opp. $T2^a$ (p. 131); Scheme XIIII opp. $V3^a$ (p. 141); Scheme XV opp. $V4^a$ (p. 143); Scheme [XVII] opp. $X4^B$ (p. 152); Scheme XVIII opp. $Y1^a$ (p. 153); Scheme XIX opp. $Y1^B$ (p. 154); Scheme [XX] opp. $Y2^a$ (p. 155); Scheme [XXI] opp. $Z1^B$ (p. 162); Scheme XVI opp. $Z2^a$ (p. 163); Scheme XXII opp. $Z3^B$ (p. 166); Scheme XXIII opp. $2A1^B$ (p. 170); Scheme XXIV opp. $2A4^a$ (p. 175); Scheme Xxv opp. $2B3^a$ (p. 181); Scheme XXVI opp. $2B3^b$ (p. 182); Scheme XXVII opp. $2C2^a$ (p. 187); Scheme XXVIII opp. $2D1^a$ (p. 193); Scheme XXIX opp. $2D2^a$ (p. 195); Scheme XXX opp. $2D3^a$ (p. 197); Scheme XXXI opp. $2D3^b$ (p. 198); Scheme XXXII opp. $2E2^a$ (p. 203); Scheme XXXIII opp. $2E4^a$ (p. 207); Scheme XXXIV opp. $2F1^b$ (p. 210); Scheme XXXV opp. $2F2^a$ (p. 211); Scheme XXXVI opp. $2F4^a$ (p. 215); Scheme XXXVII opp. $2G2^b$ (p. 220); Scheme XXXVIII opp. $2K3^a$ (p. 245).

Further Reading The classic account of the peculiarities of signatures and catchwords is R.A. Sayce's *Compositorial Practices and the Localization of Printed Books, 1530-1800*. This first appeared as an article in the fifth series of *The Library* 21 (Volume 1, March 1966): 1-45, but is now best consulted in the Oxford Bibliographical Society's reprint (Oxford, 1979), which includes a memoir of Sayce and seven pages of addenda and corrigenda from the author's notes. R.B. McKerrow's *An Introduction to Bibliography for Literary Students* (Oxford, 1927) and Philip Gaskell's *A New Introduction to Bibliography* (Oxford, 1972) are standard sources: both contain much information about catchwords, signatures, and collation easily accessible through excellent indexes.

Stray notes on the subject, often the result of recreational reading, or by-products of research continue to appear in the bibliographical journals. The study of the rare sign of W, for instance, has become an antipodean specialty: B.J. McMullin's "Gatherings Signed 'W': A Footnote to Sayce" appeared in the *Bulletin of the Bibliographical Society of Australia and New Zealand* in 1982 and has inspired (to date) seven footnotes to his footnote.

Robert Hooke. *Micrographia.* London, 1665. THE WARNOCK LIBRARY


HOOKE
MICROGRAPHIA
1665

By the Council of the ROYAL SOCIETY of *London* for Improving of Natural Knowledge.

Ordered, *That the Book written by* Robert Hooke, *M.A. Fellow of this Society, Entituled*, Micrographia, or ſome Phyſiological Deſcriptions of Minute Bodies, made by Magnifying Glaſſes, with Obſervations and Inquiries thereupon, *Be printed by* John Martyn, *and* James Alleſtry, *Printers to the ſaid Society.*

Novem. 23.
1664.

BROUNCKER. *P.R.S.*

MICROGRAPHIA:

OR SOME

Phyſiological Deſcriptions

OF

MINUTE BODIES

MADE BY

MAGNIFYING GLASSES.

WITH

OBSERVATIONS and INQUIRIES thereupon.

By *R. HOOKE*, Fellow of the ROYAL SOCIETY.

Non poſſis oculo quantum contendere Linceus,
Non tamen idcirco contemnas Lippus inungi. Horat. Ep. lib. 1.

LONDON, Printed by *Jo. Martyn*, and *Ja. Alleſtry*, Printers to the ROYAL SOCIETY, and are to be ſold at their Shop at the *Bell* in S. *Paul's* Church-yard. M DC LXV.